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Predictors of Long-Term Survival After Coronary Artery Bypass Grafting Surgery

Results From the Society of Thoracic Surgeons Adult Cardiac Surgery Database (The ASCERT Study)

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***Background*—**Most survival prediction models for coronary artery bypass grafting surgery are limited to in-hospital or 30-day end points. We estimate a long-term survival model using data from the Society of Thoracic Surgeons Adult Cardiac Surgery Database and Centers for Medicare and Medicaid Services.

***Methods and Results*—**The final study cohort included 348 341 isolated coronary artery bypass grafting patients aged ≥65 years, discharged between January 1, 2002, and December 31, 2007, from 917 Society of Thoracic Surgeons–participating hospitals, randomly divided into training (n=174 506) and validation (n=173 835) samples. Through linkage with Centers for Medicare and Medicaid Services claims data, we ascertained vital status from date of surgery through December 31, 2008 (1- to 6-year follow-up). Because the proportional hazards assumption was violated, we fit 4 Cox regression models conditional on being alive at the beginning of the following intervals: 0 to 30 days, 31 to 180 days, 181 days to 2 years, and >2 years. Kaplan-Meier–estimated mortality was 3.2% at 30 days, 6.4% at 180 days, 8.1% at 1 year, and 23.3% at 3 years of follow-up. Harrell's C statistic for predicting overall survival time was 0.732. Some risk factors (eg, emergency status, shock, reoperation) were strong predictors of short-term outcome but, for early survivors, became nonsignificant within 2 years. The adverse impact of some other risk factors (eg, dialysis-dependent renal failure, insulin-dependent diabetes mellitus) continued to increase.

***Conclusions*—**Using clinical registry data and longitudinal claims data, we developed a long-term survival prediction model for isolated coronary artery bypass grafting. This provides valuable information for shared decision making, comparative effectiveness research, quality improvement, and provider profiling. **(*Circulation*. 2012;125:1491-1500.)**

Key Words: CABG ■ long-term outcomes ■ registries ■ risk factors ■ survival analysis

Risk-adjusted mortality after coronary artery bypass grafting (CABG) surgery has been the dominant cardiac surgery outcome metric for >2 decades. Ideally, these rates are based on audited clinical data registries such as those maintained by the Society of Thoracic Surgeons (STS), state and federal government agencies, and regional collaboratives. Clinical registries include important preoperative, intraoperative, and postoperative variables that are typically unavailable in administrative data sources. Analyses of risk-adjusted clinical outcomes data from these registries have been used for a variety of quality assessment and improvement activities as well as for clinical research.

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Editorial see p 1475
Clinical Perspective on p 1500

Despite their many advantages, clinical registries also have an important limitation. Because of cost and other practical barriers, most clinical data registries collect only in-hospital or 30-day postoperative outcomes, including mortality. Ascertainment of longer-term vital status is especially problematic for referral centers whose patients are often returned to the care of their primary physicians in distant cities or states. Because many important events occur after the index hospitalization, this limited long-term follow-up is a significant barrier to the optimal utilization of registry data. Particularly as short-term procedural mortality has decreased, longer-term outcomes are of equal or greater relevance to patients, providers, and other stakeholders.

If robust, long-term follow-up data were available, it would enable investigators to study the association of these outcomes with relevant clinical factors (eg, patient characteristics and disease severity on admission). Longitudinal data would greatly enhance shared decision making, individualized patient management strategies, the study of long-term efficacy and safety, and comparative effectiveness research.

The American College of Cardiology Foundation, the STS, and the Duke Clinical Research Institute are collaborating on a comparative effectiveness study (American College of Cardiology Foundation–Society of Thoracic Surgeons Collaboration on the Comparative Effectiveness of Revascularization Strategies [ASCERT]) of CABG and percutaneous coronary interventions (PCI), funded by the National Heart, Lung, and Blood Institute of the National Institutes of Health.[1] The first aim of the ASCERT study is to develop novel, long-term mortality risk prediction models for CABG and PCI. By linking the STS Adult Cardiac Surgery Database and the Center for Medicare and Medicaid Services (CMS) 100% denominator file,[2] we developed long-term mortality models that estimate the time-dependent effect of preoperative patient factors on medium- and long-term mortality after CABG.

Methods

Institutional Review Board Approval

This analysis has been reviewed and approved by the Duke University Health System institutional review board under protocol No. Pro00019987.

Patients

The study population consisted of isolated CABG patients at STS-participating hospitals who were discharged between January 1, 2002, and December 31, 2007, and whose clinical data were collected with the use of STS Adult Cardiac Surgery Database version 2.41 and 2.52 data specifications.[3] Data quality in the STS database has been shown to be high. In audits of STS data from 12 sites in Iowa conducted by the Iowa Foundation for Medical Care in 2001–2002 (corresponding to the earliest data used for the present study), the overall agreement rate for risk predictors was 96%.[4] External audits of the entire STS national database currently include 5% of randomly selected participants annually, and the overall agreement rate for 2009 records (>70 data elements in each) was 96.1%.

Patients aged <65 years or having a history of coma were excluded, as were patients with missing data on age, sex, or status (elective, urgent, emergent, salvage). For patients with multiple operations in the data set, only the first operation was included. The final study population included 348 341 patients from 917 STS-participating hospitals (Figure 1).

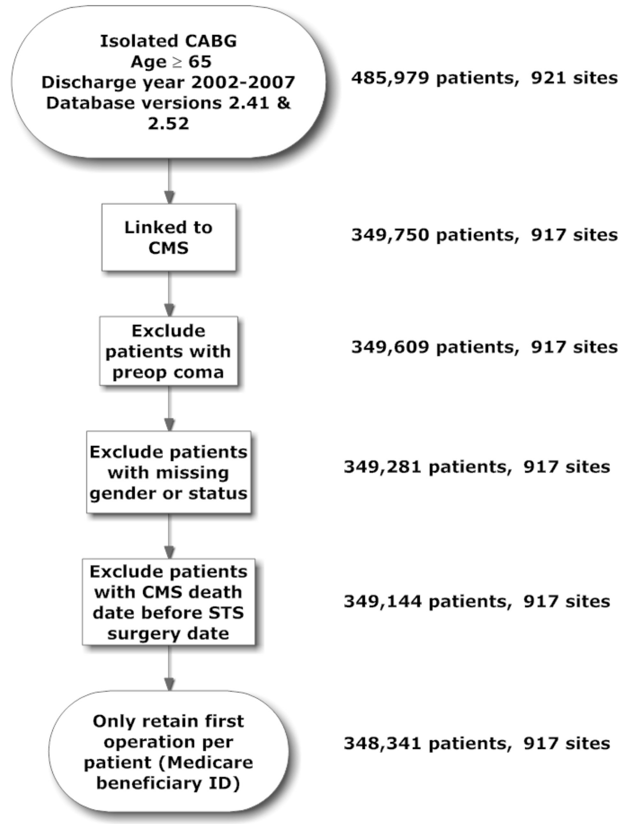

Figure 1. Eligibility and exclusion flowchart. CABG indicates coronary artery bypass grafting; CMS, Center for Medicare and Medicaid Services; preop, preoperative; STS, Society of Thoracic Surgeons; and ID, identification.

Mortality Ascertainment

Procedural records in the STS database were linked to CMS inpatient claims and denominator databases.[2,5] STS and CMS claims records from 2003 to 2007 were considered to be a match if they agreed exactly on site, sex, admission date, discharge date, date of birth (if present), and age. For 2002, dates of birth, admission, and discharge were coarsened to protect confidentiality, and thus a more complicated matching criterion was required. Records were considered to be a match if they agreed exactly on site, sex, length of stay, procedure month and year, days from birth to admission (if present), age, and days from admission to surgery. Overall, 86.5% of records were collected during 2003 to 2007 and matched exactly on all available matching criteria. In a validation study of this methodology in which heart failure patients from Duke University were used,[5] the estimated false match rate was 0% (0/109) when the most stringent matching criterion was used and 1% (1/109) when a less stringent matching rule was used.

Vital status and dates of death through December 31, 2008, were obtained by linking CMS claims records to the denominator file on the basis of an encrypted Medicare patient identifier. Follow-up was considered to be administratively censored on December 31, 2008, and was at least 1 year for all patients (median, 4 years; maximum, 7 years).

Predictor Variables

Predictor variables were summarized as percentages if categorical and as mean, median, SD, and quartiles (25th, 75th) if continuous.

Predictors were chosen on the basis of published CABG short-term models[6] and clinical experience. Variable definitions are available at http://www.sts.org. The variable for "number of diseased vessels" in the STS Adult Cardiac Surgery Database was designed to reflect the amount of myocardium at risk. Thus, although patients with significant left main coronary disease are specifically identified by a separate dichotomous variable, for the purposes of defining myocardium at risk, they are also classified as 2 diseased vessels.

Development and Validation Samples

Data were randomly divided into a 50% training sample (n=174 506) to determine the form of the model and estimate regression coefficients and a 50% validation sample (n=173 835) to assess model calibration and discrimination.

Statistical Analysis

Form of Model

We estimated survival as a function of patient preoperative characteristics using the Cox proportional hazards model.[7] The proportional hazards assumption was investigated by plotting and visually inspecting transformed (log-log) survival probabilities versus time after CABG. To allow for non–proportional hazards, we estimated separate hazard ratio parameters for all model variables for each of the following time intervals: 0 to 30 days, 31 to 180 days, 181 days to 2 years, and >2 years. Time intervals were chosen after we conducted a preliminary analysis that involved fitting Cox models with several relatively narrow categories, then collapsing adjacent categories on the basis of a combination of statistical and nonstatistical considerations. The first cut point (30 days) was chosen for consistency with many existing short-term CABG mortality models and quality metrics. As the ability to support even the most seriously ill postoperative patients has increased as a result of modern critical care, some have suggested that our definition of the "early" postoperative period should likewise be lengthened so as not to underestimate early risk.[8] This was the basis for our relatively narrow second time interval, 31 to 180 days. The remaining intervals were chosen by collapsing adjacent categories for which the hazard ratios appeared most similar while retaining sufficient events in each to ensure precise estimation of category-specific hazard ratio parameters.

We fit 4 separate Cox regression models that were conditional on being alive at the beginning of each time interval. Mathematically, this was equivalent to fitting a single Cox model with piecewise constant, time-dependent hazard ratios for all model variables.

Functional Form of Predictors

Graphical exploratory analyses were used to determine the functional form of continuous variables and to decide whether categorical variables with several categories could be collapsed into fewer categories. In a preliminary Cox model in which flexible regression splines for continuous variables were used, plots of the variables age, height, and year of surgery revealed an approximately linear association with the log-hazard of mortality and were modeled as linear. The association between body mass index and mortality was determined to be nonmonotone (U shaped) and was modeled as a continuous polynomial regression function with linear and quadratic effects. We arbitrarily selected body mass indices of 20, 30, 35, and 40 kg/m^2 to compare their hazard ratios relative to a "normal" reference body mass index of 25 kg/m^2. For modeling renal function, patients on dialysis were adequately represented by an indicator variable for dialysis without further adjustment for the patient's last preoperative creatinine level. For patients not on dialysis, the relationship between last preoperative creatinine and mortality was modeled as a straight line with a change of slope at 1.5 mg/dL. Ejection fraction was modeled as linear <60% and constant >60%. Finally, aortic stenosis pressure gradient was modeled as linear <77 mm Hg and constant >77 mm Hg (the 99th percentile).

Interactions

Interactions between predictors were examined by identifying 5 predictors with the highest global χ^2 statistics and creating all possible pairwise interactions among them, in each case considering whether these were also clinically plausible. Although some interaction terms were statistically significant, they were not believed to be of major practical significance. Measures of model calibration and discrimination were not materially affected by their inclusion (ie, model fit was not substantially improved), and models without interactions were also considered to be substantially more interpretable and usable. Therefore, we retained only main effects in the final model.

Missing Data

Predictor data were highly complete, with most covariates having <1% missing data (Table I in the online-only Data Supplement). Missing values were imputed to the median of continuous variables (after stratifying on relevant variables to enhance prediction of the missing value) and the most common category of binary and polytomous variables. More computationally intensive missing data strategies, such as multiple imputations, were not used for this analysis because they have been documented to have minimal impact in previous STS risk models.[9]

Model Assessment

Model performance was assessed in the 50% validation sample. Predicted survival curves were generated by applying estimated regression coefficients from the development sample to covariate data of patients in the validation sample. To assess calibration (fit), model-based predicted survival curves were averaged across patients in the validation sample and compared with nonparametric (Kaplan-Meier) survival curves. This was done in the overall validation population and in various subgroups. To further assess calibration, patients in the validation sample were ranked into 20 categories on the basis of their estimated risk of dying within 3 years. Average expected and observed (Kaplan-Meier) 3-year survival probabilities were then calculated within each category and plotted.

Discrimination was quantified by 2 methods. First, discrimination for predicting mortality status as a dichotomous end point (alive/dead) was assessed by the area under the receiver operating characteristic curve (C index) for 3 selected time points: 30 days, 1 year, and 3 years. All patients had at least 1 year of follow-up and were included in the estimation of discrimination for the 30-day and 1-year time points. For the 3-year time point, the 65% of patients with at least 3 years of potential follow-up (ie, those treated between January 1, 2004, and December 31, 2005) were included. Second, an analogous overall measure of discrimination for predicting survival time as a continuous variable was calculated with the use of Harrell's C index for censored survival data.[10] To apply Harrell's method, patients were ranked according to their predicted 3-year mortality risk. We then calculated the proportion of pairs of patients for which the patient with the lower predicted probability of mortality survived longer than the patient with the higher predicted probability, accounting appropriately for censoring.

Final Model

After model development and validation were completed, we reestimated the final model coefficients on the basis of the complete data set (development plus validation samples). Confidence intervals for hazard ratios were calculated with sandwich SE estimates to account for within-hospital clustering.[11]

Results

Table II in the online-only Data Supplement compares the characteristics of STS CABG patients who were or were not matched to CMS. For most variables, these 2 groups were quite similar.

Table 1 depicts the characteristics of the final study population of 348 341 patients who underwent isolated CABG. Kaplan-Meier estimated mortality in the overall study cohort (development and validation samples) was 3.2% at 30 days, 6.4% at 180 days, 8.1% at 1 year, 11.3% at 2 years, and

Table 1. Characteristics of the Overall Study Population

Characteristics	No.	Summary Statistics
Total study population	348 341	100
Age, y		
Median (25th, 75th percentiles)		73 (69, 78)
Mean±SD		73±6
Female	112 146	32
White	312 482	90
Black	14 562	4
Hispanic	7871	2
Weight, kg		
Median (25th, 75th percentiles)		82 (71, 93)
Mean±SD		83±17
Height, cm		
Median (25th, 75th percentiles)		172 (163, 178)
Mean±SD		170±11
Body mass index, kg/m^2		
Median (25th, 75th percentiles)		28 (25, 31)
Mean±SD		28±5
Current smoker	45 901	13
Past smoker	152 517	44
Diabetes mellitus	124 091	36
Non–insulin-dependent diabetes mellitus	90 743	26
Insulin-dependent diabetes mellitus	33 348	10
Last creatinine level, mg/dL		
Median (25th, 75th percentiles)		1 (0.9, 1.3)
Mean±SD		1±0.7
Renal failure	21 754	6
Dialysis	4858	1
Hypertension	285 765	82
Chronic lung disease	73 780	21
Mild	39 156	11
Moderate	22 406	7
Severe	12 218	4
Immunosuppressive therapy	7652	2
Peripheral vascular disease	66 050	19
Cerebrovascular disease	63 323	18
Cerebrovascular accident	30 621	9
≤2 wk	922	0.3
>2 wk	29 699	9
RIND	301	0.1
Transient ischemic attack	13 286	4
Carotid stenosis >75%	10 006	3
Prior carotid surgery	16 355	5
Prior CABG	18 725	5
Prior valve surgery	1316	0.4
Previous PCI	69 666	20
PCI within 6 h	3064	0.9
Myocardial infarction	149 138	43
≤6 h	4377	1
>6 h and <24 h	8260	2
1–7 d	63 370	18
8–21 d	12 386	4
>21 d	60 745	17
NYHA class I	43 012	13
NYHA class II	88 788	27
NYHA class III	130 488	39
NYHA class IV	72 887	22
Congestive heart failure	52 174	15
NYHA class <IV	33 027	10
NYHA class IV	19 147	6
Stable angina	144 701	42
Unstable angina	136 897	39
Cardiogenic shock	6224	2
Arrhythmia	39 363	11
Atrial fibrillation/flutter	25 636	7
Preoperative β-blocker	244 572	70
Preoperative inotrope	6616	2
Preoperative IABP	24 083	7
1 diseased vessel	11 498	3
2 diseased vessels	63 736	18
3 diseased vessels	271 295	78
Left main disease >50%	109 544	32
Ejection fraction, %		
Median (25th, 75th percentiles)		53 (42, 60)
Mean±SD		51±13
Aortic stenosis	7850	2
Aortic insufficiency	15 854	5
Mild	12 985	4
Moderate	2628	0.8
Severe	241	0.1
Mitral insufficiency	47 380	14
Mild	35 658	11
Moderate	10 541	3
Severe	1181	0.3
Tricuspid insufficiency	23 133	7
Mild	18 765	6
Moderate	3924	1
Severe	444	0.1
Previous cardiovascular surgeries		
None	323 660	94
1	19 772	6
≥2	2163	0.6
Status		
Elective	173 608	50
Urgent	159 845	46
Emergent	14 095	4
Emergent salvage	793	0.2

Summary statistics are percentages unless indicated otherwise. RIND indicates reversible ischemic neurological deficit; CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention; NYHA, New York Heart Association; and IABP, intra-aortic balloon pump.

23.3% at 3 years of follow-up. Table III in the online-only Data Supplement summarizes the univariable association between each candidate predictor variable and estimated mortality rates at 30 days, 1 year, and 3 years.

Table 2 shows hazard ratios derived by fitting multivariable Cox regression models to 4 time intervals (see Methods). In multivariable analyses, several distinct, temporal risk factor patterns are evident. For example, higher ejection fraction was protective over all time periods, and the magnitude of effect was stable. Conversely, past history of a stroke, transient ischemic attack, or reversible ischemic neurological deficit, moderate or severe chronic lung disease, or immunosuppressive treatment had a significant negative impact on survival at all end points. The magnitude of effect of some important early predictors of risk, including current smoking, insulin-dependent diabetes mellitus, and dialysis-dependent renal failure, increased over time, suggesting an accumulation of risk from these debilitating chronic behaviors and diseases. On the other hand, the effect of some important early predictors of increased mortality (eg, emergency status, cardiogenic shock, acute preoperative myocardial infarction, and reoperation) diminished rather quickly and became nonsignificant for those patients who survived the early postoperative and recovery periods.

Our results confirm the so-called obesity paradox reported in other short-term analyses[12,13] and demonstrate that these effects persist for at least 2 years postoperatively. Low body mass index (20 versus 25 kg/m^2) predicted higher mortality at all time periods postoperatively, whereas obesity (>25 kg/m^2) was associated with decreased risk.

Model discrimination (C index) in the validation set was 0.762 for predicting 30-day status, 0.764 for predicting 1-year status, and 0.748 for predicting 3-year status. Harrell's C statistic for predicting overall survival time was 0.732. Thirty-day model discrimination differs from that observed in our most recent STS isolated CABG risk models,[6] most likely because the present model is limited to patients aged >65 years. Model discrimination at longer time intervals is also lower than that in the early postoperative period. As the time interval from surgery increases, there is correspondingly greater probability that other factors not included in the risk models may affect survival.

Figure 2 depicts the expected and Kaplan-Meier observed survival curves for the overall validation cohort. Figure 3 compares observed and expected 3-year mortality risk across 20 categories of predicted risk. Within the typical range of expected mortalities, prediction is highly accurate. From 20% to 40% expected mortality, there is very slight underestimation of mortality risk, and at the highest expected mortality (>50%), there is slight overestimation. Figure 4 depicts Kaplan-Meier observed and expected survival curves for selected patient subgroups in the validation cohort. The expected (solid) and observed (dashed) lines are nearly superimposable on most of the plots.

Discussion

Short-term duration of follow-up has prevented the full potential of clinical data registries from being realized. As average acute hospital length of stay has shortened, procedure-related deaths and complications are correspondingly more likely to occur after patients have been discharged from the hospital. The use of advanced mechanical and pharmacological support has increasingly prolonged the lives of many critically ill postoperative patients, and such patients may be transferred to long-term critical care facilities on ventilators or dialysis. Deaths among such patients may not occur for months after their index hospital discharge, and these delayed postoperative deaths would not be captured in most existing clinical registries.[8] Short-term follow-up is also a major limitation of comparative effectiveness studies of various treatment strategies, such as CABG or PCI for coronary artery disease. Differences in efficacy of alternative treatments are often not apparent for months or years, much longer than the typical end points in most clinical registries. Finally, some preoperative risk factors may have little impact on short-term mortality but are major considerations in the longer term and vice versa.

Some previous studies have assessed the long-term impact of preoperative risk factors, operative and perioperative care processes, and postoperative complications.[14–28] Our study focuses specifically on the former, and it addresses the major limitations of these earlier studies. Many are from single institutions, and their inferences may be confounded by idiosyncratic hospital practice patterns. Most prior studies include only a few hundred to a few thousand patients and lack the power to identify the full spectrum of factors associated with outcomes. Some studies of long-term CABG mortality have been based solely on large administrative databases. This strategy ensures adequate sample size and provides valuable information regarding vital status, readmissions, reinterventions, costs, aggregate resource utilization, and outpatient activities. However, administrative databases have a number of well-known deficiencies that limit their usefulness in clinical research, including misclassification of procedures and diagnoses; unavailability of important clinical variables; inability to distinguish comorbidities from complications (in the absence of Present on Admission indicators); and focus on narrow patient populations[29–34] There are studies of long-term CABG outcome predictors based on clinical registries, but these are derived from data that are 10 to 20 years old and may not reflect current patient condition severity and surgical practice.[35,36]

Our study seeks to overcome the inherent limitations of both clinical and administrative data registries by linking the 2 together. This approach compensates for their individual deficiencies while harnessing their complementary strengths. The resulting linked data retain the granularity and clinical detail of clinical registries while adding long-term outcomes and cost data available in administrative data sources. These linked data are ideally suited to studies of long-term clinical outcomes, comparative effectiveness, resource utilization, and provider performance for particular types of patients.

Using predicted long-term outcomes tailored to their specific risk profiles, patients may more effectively participate in shared decision making with their providers. Awareness of both the short-term and long-term risks and benefits (eg, survival, complications, quality of life) might assist patients in deciding whether or not to proceed with surgery. Further-

Table 2. Cox Model Hazard Ratios

Risk Factor	Hazard Ratio (95% CI) 0–30 d (No. of Deaths=11 062)	31–180 d (No. of Deaths=11 075)	181 d to 2 y (No. of Deaths=10 155)	≥2 y (No. of Deaths=28 164)
Age, increment of 10	1.77 (1.71–1.83)	1.97 (1.90–2.04)	1.79 (1.74–1.84)	2.00 (1.95–2.05)
Aortic insufficiency, moderate/severe	1.23 (1.04–1.45)	1.19 (1.01–1.40)	1.19 (1.03–1.36)	1.07 (0.94–1.21)
Aortic stenosis, aortic gradient truncated at 77 mm Hg, linear increment of 10	1.10 (1.05–1.15)	1.10 (1.06–1.15)	1.15 (1.11–1.19)	1.14 (1.11–1.18)
BMI 20 vs 25	1.11 (1.08–1.14)	1.17 (1.14–1.20)	1.18 (1.16–1.21)	1.10 (1.08–1.12)
BMI 30 vs 25	0.93 (0.91, 0.96)	0.90 (0.88–0.92)	0.88 (0.87–0.90)	0.94 (0.92–0.95)
BMI 35 vs 25	0.91 (0.87–0.94)	0.85 (0.82–0.88)	0.81 (0.79–0.84)	0.90 (0.88–0.93)
BMI 40 vs 25	0.91 (0.86–0.96)	0.84 (0.79–0.89)	0.79 (0.75–0.82)	0.89 (0.86–0.93)
CHF, NYHA class IV	1.28 (1.19–1.37)	1.47 (1.37–1.57)	1.43 (1.35–1.51)	1.26 (1.19–1.32)
CHF, not NYHA class IV	1.25 (1.18–1.33)	1.48 (1.39–1.56)	1.42 (1.35–1.49)	1.38 (1.32–1.43)
Chronic lung disease ≥ moderate	1.56 (1.48–1.65)	1.75 (1.66–1.85)	1.62 (1.55–1.70)	1.56 (1.50–1.62)
Creatinine 1.5 vs 1.0 (patients not on dialysis)	1.38 (1.32–1.44)	1.46 (1.39–1.52)	1.29 (1.24–1.34)	1.24 (1.21–1.28)
Creatinine 2.0 vs 1.0 (patients not on dialysis)	1.58 (1.52–1.65)	1.75 (1.68–1.82)	1.56 (1.50–1.62)	1.53 (1.49–1.58)
Creatinine 2.5 vs 1.0 (patients not on dialysis)	1.81 (1.71–1.92)	2.10 (1.99–2.21)	1.87 (1.79–1.96)	1.89 (1.81–1.97)
Current smoker	1.19 (1.11–1.27)	1.40 (1.31–1.50)	1.60 (1.52–1.69)	1.67 (1.60–1.74)
CVA/TIA/RIND	1.22 (1.16–1.29)	1.41 (1.35–1.49)	1.38 (1.33–1.44)	1.29 (1.25–1.33)
Date of surgery, per year	0.98 (0.96–0.99)	0.99 (0.98–1.01)	0.99 (0.98–1.00)	0.98 (0.97–1.00)
Diabetes mellitus, insulin-dependent	1.21 (1.15–1.28)	1.59 (1.50–1.68)	1.61 (1.53–1.69)	1.77 (1.71–1.84)
Diabetes mellitus, non–insulin-dependent	0.96 (0.91–1.00)	1.25 (1.20–1.31)	1.21 (1.17–1.26)	1.30 (1.27–1.34)
Dialysis vs creatinine=1.0	2.93 (2.66–3.24)	4.13 (3.77–4.53)	4.57 (4.26–4.91)	4.46 (4.12–4.82)
EF truncated at 60, increment of 10	0.88 (0.86–0.90)	0.85 (0.84–0.87)	0.85 (0.84–0.86)	0.87 (0.86–0.88)
Ethnicity, Hispanic	1.09 (0.96–1.24)	1.06 (0.93–1.20)	1.11 (1.00–1.23)	0.99 (0.91–1.08)
Height by 10 cm	0.94 (0.92–0.96)	0.98 (0.96–1.01)	0.98 (0.96–1.00)	1.02 (1.00–1.03)
Hypertension	1.04 (0.98–1.10)	1.02 (0.96–1.08)	1.05 (1.00–1.09)	1.04 (1.00–1.08)
Immunosuppressive treatment	1.46 (1.33–1.60)	1.75 (1.60–1.91)	1.60 (1.47–1.74)	1.44 (1.34–1.53)
Left main disease >50%	1.01 (0.97–1.05)	1.05 (1.01–1.10)	1.12 (1.08–1.16)	1.06 (1.03–1.09)
MI <6 h	1.53 (1.36–1.74)	1.18 (1.01–1.37)	1.22 (1.05–1.41)	0.94 (0.82–1.08)
MI 1–21 d	1.36 (1.29–1.43)	1.20 (1.14–1.26)	0.99 (0.95–1.03)	1.04 (1.01–1.08)
MI 6 to 24 h	1.61 (1.45–1.79)	1.16 (1.02–1.31)	1.10 (0.99–1.23)	0.92 (0.84–1.01)
Mitral insufficiency, moderate/severe	1.14 (1.05–1.24)	1.17 (1.08–1.27)	1.07 (1.00–1.15)	1.15 (1.09–1.22)
Noninvasive study, carotid stenosis >75%	1.17 (1.06–1.28)	1.08 (0.98–1.20)	1.08 (0.99–1.18)	1.15 (1.08–1.23)
Past smoker	1.08 (1.03–1.14)	1.17 (1.12–1.22)	1.26 (1.22–1.32)	1.23 (1.19–1.26)
PCI within 6 h	1.32 (1.16–1.49)	1.09 (0.91–1.31)	1.06 (0.88–1.28)	1.09 (0.95–1.25)
Peripheral vascular disease	1.33 (1.27–1.39)	1.40 (1.34–1.45)	1.37 (1.32–1.42)	1.30 (1.27–1.34)
Preoperative atrial fibrillation	1.28 (1.20–1.36)	1.55 (1.47–1.63)	1.47 (1.40–1.54)	1.40 (1.35–1.46)
Preoperative IABP/inotropes	1.30 (1.21–1.39)	1.15 (1.08–1.23)	1.05 (0.99–1.11)	0.97 (0.93–1.02)
Prior carotid surgery	1.19 (1.10–1.28)	1.08 (1.00–1.17)	1.05 (0.98–1.11)	1.17 (1.11–1.23)
Race, Asian	0.98 (0.82–1.19)	0.90 (0.75–1.08)	0.93 (0.78–1.10)	0.85 (0.74–0.97)
Race, black	0.94 (0.84–1.06)	1.18 (1.08–1.29)	1.22 (1.14–1.31)	1.07 (1.01–1.13)
Reoperation, 1 previous operation	1.85 (1.72–1.99)	1.26 (1.17–1.36)	1.16 (1.09–1.23)	1.11 (1.06–1.16)
Reoperation, ≥2 previous operations	2.35 (1.96–2.82)	1.53 (1.24–1.89)	1.54 (1.30–1.82)	1.14 (0.99–1.30)
Sex, male	0.70 (0.66–0.73)	0.75 (0.71–0.80)	0.98 (0.93–1.02)	0.95 (0.92–0.98)
Shock	1.96 (1.78–2.16)	1.48 (1.32–1.65)	1.01 (0.90–1.14)	1.01 (0.91–1.13)
Status, emergent (no resuscitation)	1.90 (1.73–2.09)	1.44 (1.29–1.61)	1.03 (0.94–1.14)	0.98 (0.91–1.06)
Status, emergent with resuscitation or salvage	4.31 (3.75–4.95)	2.04 (1.66–2.51)	1.36 (1.09–1.70)	1.05 (0.83–1.32)
Status, urgent	1.17 (1.10–1.23)	1.16 (1.11–1.22)	1.04 (1.00–1.08)	1.01 (0.98–1.04)
3 diseased vessels	1.28 (1.13–1.44)	1.12 (1.00–1.26)	0.98 (0.90–1.08)	1.12 (1.04–1.21)

(*Continued*)

Table 2. Continued

Risk Factor	Hazard Ratio (95% CI) 0–30 d (No. of Deaths=11 062)	31–180 d (No. of Deaths=11 075)	181 d to 2 y (No. of Deaths=10 155)	≥2 y (No. of Deaths=28 164)
Tricuspid insufficiency, moderate/severe	1.20 (1.07–1.35)	1.23 (1.09–1.39)	1.22 (1.09–1.36)	1.00 (0.89–1.11)
2 diseased vessels	1.08 (0.95–1.22)	1.05 (0.93–1.19)	0.98 (0.89–1.08)	1.06 (0.98–1.15)
Unstable angina, no MI	1.14 (1.08–1.20)	1.00 (0.95–1.05)	0.99 (0.95–1.03)	0.97 (0.94–1.01)

BMI indicates body mass index; CHF, congestive heart failure; NYHA, New York Heart Association; CVA, cerebrovascular accident; TIA, transient ischemic attack; RIND, reversible ischemic neurological deficit; EF, ejection fraction; MI, myocardial infarction; PCI, percutaneous coronary intervention; and IABP, intra-aortic balloon pump.

more, just as short-term outcomes vary among providers, it is possible that long-term outcomes may also vary, and such information could be useful for all stakeholders.

The long-term CABG mortality model described in this report, based solely on preoperative patient characteristics, is only the first of many applications we envision to exploit the advantages of linked registries. In addition to mortality, it will also be possible to study other long-term end points such as readmissions, reinterventions, and cumulative costs and resource use. Other models will estimate the effect of intraoperative decisions, such as use of all-arterial grafting or off-pump procedures, on long-term outcomes. Combined with preoperative variables, such information could help to determine the specific procedures or perioperative strategies that are most useful for specific types of patients. The addition of early postoperative events (eg, stroke or mediastinitis) as predictor variables would permit more effective discussions with such patients regarding their long-term health expectations.

Linkages with CMS and other administrative data sources will also enhance the accuracy of outcomes data used to calculate performance metrics such as the STS CABG composite scores.[37,38] For example, ongoing linkages with the Social Security Death Master File or National Death Index would permit continuous input and validation of vital status for patients of all ages, not just the Medicare population.[39]

Linked clinical and administrative data will facilitate the determination of risk-adjusted, long-term freedom from reoperation and readmission not only for surgical procedures but also for a variety of medical devices, such as cardiac valve prostheses. This ability to capture objective long-term patient status, coupled with extensive clinical data from the perioperative period, will be a marked improvement over existing methods for postmarket surveillance.

Linkages to other clinical registries will also be useful, and their combined utility will be further enhanced by linking to administrative data, as demonstrated by the ASCERT comparative effectiveness study.[1] Furthermore, as payment strategies evolve from a focus on procedures or acute hospitalizations to episodes of care, the ability to link related clinical registries (eg, cardiology and cardiac surgery) will facilitate the study and implementation of these reimbursement poli-

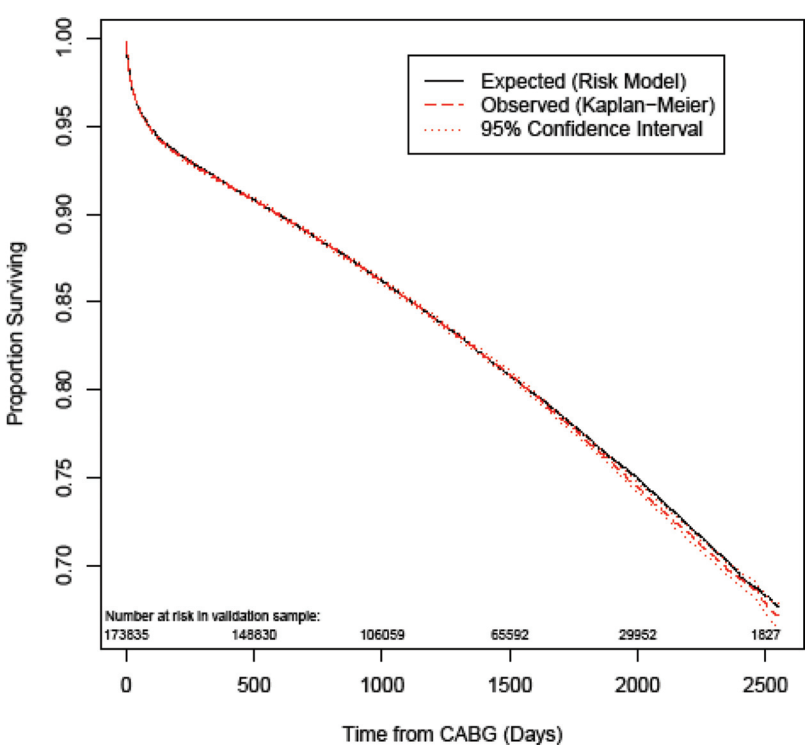

Figure 2. Expected and Kaplan-Meier observed survival curves for the validation cohort, with numbers of patients at risk. CABG indicates coronary artery bypass grafting.

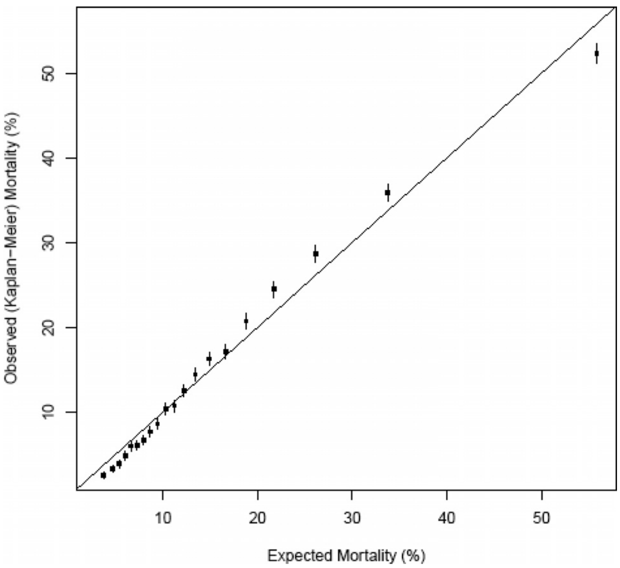

Figure 3. Observed and expected 3-year mortality by categories of expected risk in the validation cohort.

cies. Finally, linkages between clinical and payer registries would provide unique information such as outpatient visits, compliance with medications, and cumulative resource use.

Limitations

There are inherent limitations to any studies that use voluntarily collected data, but these are mitigated by the robust STS audit program described previously.

To obtain accurate long-term follow-up, it was necessary to link our data to CMS claims data. Because Medicare claims data are restricted to patients aged ≥65 years, the generalizability of our findings to younger populations is uncertain.

It was impossible to accurately determine cause of death (eg, cardiac versus noncardiac), and our analyses use all-cause mortality as the end point.

Our linkages are based on combinations of indirect identifiers. Previous analyses have demonstrated that nonunique identifiers can be combined to create high-quality links between a clinical registry and an administrative data set, allowing researchers to capitalize on the strengths of both types of data to answer important clinical questions.[5,40] Although we believe that this strategy yielded highly accurate matches in our study, some errors may have been introduced through this process.

Finally, the more distant from the time of surgery, the more opportunity there is for non–surgery-related events to confound the apparent associations between preoperative factors and outcomes.

Conclusions

We linked broadly representative, real-world clinical data from the STS Adult Cardiac Surgery Database and vital status from Medicare claims data to construct a robust, long-term CABG survival prediction model. Because of the large study cohort, model performance is excellent.

As the time interval from surgery lengthens, the clinical outcomes of postoperative survivors are less affected by

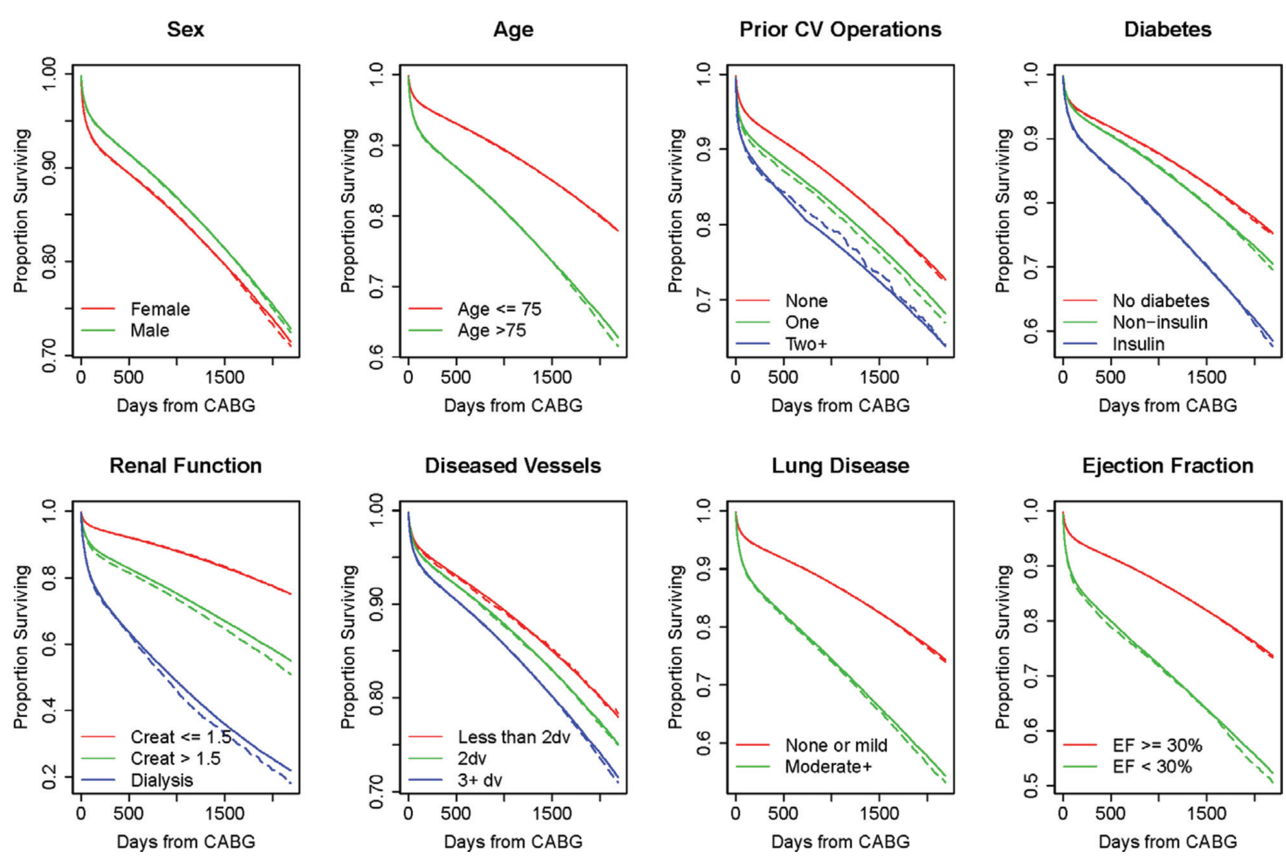

Figure 4. Kaplan-Meier observed and expected survival curves for selected patient subgroups in the validation cohort. CABG indicates coronary artery bypass grafting; CV, cardiovascular; Creat, creatinine; dv, diseased vessels; and EF, ejection fraction.

traditional predictors of early survival, such as emergency status, shock, and reoperation. Conversely, late mortality is increasingly associated with chronic diseases such as insulin-dependent diabetes mellitus and dialysis-dependent renal failure and behaviors such as smoking.

As short-term CABG mortality rates decline, the ability to estimate long-term outcomes for patients with particular risk factors will become increasingly important for shared decision making, comparative effectiveness research, optimal treatment planning, quality improvement initiatives, and provider profiling.

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CLINICAL PERSPECTIVE

Most survival prediction models for coronary artery bypass grafting surgery are limited to in-hospital or 30-day end points. However, particularly as short-term mortality rates decrease, it is increasingly important for providers, patients, payers, and other stakeholders to better understand the likelihood of long-term survival. We linked broadly representative, real-world clinical data from the Society of Thoracic Surgeons Adult Cardiac Surgery Database and vital status from Medicare claims data to construct a robust, long-term coronary artery bypass grafting surgery survival prediction model. This study included 348 341 patients aged ≥65 years who underwent isolated coronary artery bypass grafting surgery between 2002 and 2007. Because of the large study cohort and clinical predictors, model performance is excellent. On the basis of the results of this study, late outcomes for patients who initially survive coronary artery bypass grafting surgery are less affected by traditional predictors of early mortality such as emergency status, shock, and reoperation. Conversely, late mortality is increasingly associated with chronic debilitating diseases such as insulin-dependent diabetes mellitus and dialysis-dependent renal failure and behaviors such as smoking. This is valuable information for shared decision making, comparative effectiveness research, quality improvement, patient counseling, and provider profiling.

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SUPPLEMENTAL TABLE 1: POPULATION STATISTICS AND MISSING DATA				
Factors	**Missing**	**Levels**	**No.**	**Summary Statistics**
Demographics				
Age (years)	0 (0.0%)	Median (25th, 75th)		73.0 (69.0, 78.0)
		Mean ± STD		73.5 ± 5.7
		≥65 and < 70	103,192	29.6%
		≥70 and < 75	99,488	28.6%
		≥75 and < 80	86,747	24.9%
		≥80 and < 85	46,871	13.5%
		≥85	12,043	3.5%
Gender	0 (0.0%)	Female	112,146	32.2%
		Male	236,195	67.8%
Race/Ethnicity	2222 (0.6%)	White	312,482	90.3%
		Black	14,562	4.2%
		Hispanic	7,871	2.3%
		Asian/Native American/Other	11,204	3.2%
Year of Surgery	0 (0.0%)	2002	47,188	13.5%
		2003	60,932	17.5%
		2004	60,293	17.3%
		2005	61,041	17.5%
		2006	60,891	17.5%
		2007	57,996	16.6%
Risk Factors				
Weight (Kg)	1086 (0.3%)	Median (25th, 75th)		81.6 (71.0, 93.0)
		Mean ± STD		82.7 ± 17.3
		< 70	77,252	22.2%
		≥70 and < 80	81,258	23.4%
		≥80and < 90	81,054	23.3%
		≥90	107,691	31.0%
Height (cm)	1193 (0.3%)	Median (25th, 75th)		172.0 (163.0, 178.0)
		Mean ± STD		170.4 ± 11.0
		< 160	54,672	15.7%

SUPPLEMENTAL TABLE 1: POPULATION STATISTICS AND MISSING DATA				
Factors	**Missing**	**Levels**	**No.**	**Summary Statistics**
		≥160 and <170	87,221	25.1%
		≥170and <180	129,791	37.4%
		≥180	75,464	21.7%
BMI (kg / m2)	2188 (0.6%)	Median (25th, 75th)		27.7 (24.8, 31.1)
		Mean ± STD		28.4 ± 5.3
		< 20	8,903	2.6%
		≥20 and <25	82,137	23.7%
		≥25and <30	144,621	41.8%
		≥30	110,492	31.9%
Smoking Status	1008 (0.29%)	Current Smoker	45,901	13.2%
		Past Smoker	152517	43.9%
		Never Smoked	148,915	42.9%
Diabetes	714 (0.2%)	No diabetes	223,536	64.3%
		None	5,954	1.7%
		Diet	12,133	3.5%
		Oral	72,656	20.9%
		Insulin	33,348	9.6%
Diabetes	714 (0.2%)	No diabetes	223,536	64.3%
		Non-insulin diabetes	90,743	26.1%
		Insulin diabetes	33,348	9.6%
Last Creatinine Level (mg/dL)	3052 (0.9%)	Median (25th, 75th)		1.1 (0.9, 1.3)
		Mean ± STD		1.2 ± 0.7
Renal Failure	339 (0.1%)	Yes	21,754	6.3%
		No	326,248	93.7%
Dialysis	520 (0.1%)	Yes	4,858	1.4%
		No	342,963	98.6%
Renal Function	3026 (0.9%)	No dialysis - Creatinine ≤ 1.5 mg/dL	306,587	88.8%

SUPPLEMENTAL TABLE 1: POPULATION STATISTICS AND MISSING DATA				
Factors	**Missing**	**Levels**	**No.**	**Summary Statistics**
		No dialysis - Creatinine > 1.5 mg/dL	33,870	9.8%
		Dialysis	4,858	1.4%
Hypertension	171 (0.0%)	Yes	285,765	82.1%
		No	62,405	17.9%
Chronic Lung Disease	2416 (0.7%)	No	272,145	78.7%
		Yes	73,780	21.3%
Chronic Lung Disease Severity	2416 (0.7%)	None	272,145	78.7%
		Mild	39,156	11.3%
		Moderate	22,406	6.5%
		Severe	12,218	3.5%
Immunosuppressive Therapy	466 (0.1%)	Yes	7,652	2.2%
		No	340,223	97.8%
Peripheral Vascular Disease	322 (0.1%)	Yes	66,050	19.0%
		No	281,969	81.0%
Cerebrovascular Disease	290 (0.1%)	Yes	63,323	18.2%
		No	284,728	81.8%
CVA	809 (0.2%)	No	316,911	91.2%
		Yes	30,621	8.8%
CVA Timing	809 (0.2%)	No CVA	316,911	91.2%
		≤ 2 weeks	922	0.3%
		> 2 weeks	29,699	8.5%
RIND	867 (0.2%)	Yes	301	0.1%
		No	347,173	99.9%
TIA	867 (0.2%)	Yes	13,286	3.8%
		No	334,188	96.2%
Non-invasive carotid > 75%	867 (0.2%)	Yes	10,006	2.9%
		No	337,468	97.1%
Prior Carotid Surgery	867 (0.2%)	Yes	16,355	4.7%
		No	331,119	95.3%
Prior CABG	967 (0.3%)	Yes	18,725	5.4%

SUPPLEMENTAL TABLE 1: POPULATION STATISTICS AND MISSING DATA				
Factors	**Missing**	**Levels**	**No.**	**Summary Statistics**
		No	328,649	94.6%
Prior Valve Surgery	986 (0.3%)	Yes	1,316	0.4%
		No	346,039	99.6%
Previous PCI	1080 (0.3%)	Yes	69,666	20.1%
		No	277,595	79.9%
Stent (DCF v2.41 only)	206663 (59.3%)	Yes	18,572	13.1%
		No	123,106	86.9%
PCI within 6 hrs	2297 (0.7%)	Yes	3,064	0.9%
		No	342,980	99.1%
MI	1917 (0.6%)	Yes	149,138	43.1%
		No	197,286	56.9%
MI Timing	1917 (0.6%)	≤ 6 hrs	4,377	1.3%
		> 6 hrs and < 24 hrs	8,260	2.4%
		1 - 7 days	63,370	18.3%
		8 - 21 days	12,386	3.6%
		> 21 days	60,745	17.5%
		No MI	197,286	56.9%
NYHA Classification	13166 (3.8%)	Class 1	43,012	12.8%
		Class 2	88,788	26.5%
		Class 3	130,488	38.9%
		Class 4	72,887	21.7%
CHF	2076 (0.6%)	No	294,091	84.9%
		Yes	52,174	15.1%
CHF - NYHA Classification	2076 (0.6%)	No CHF	294,091	84.9%
		CHF - NYHA less than class 4	33,027	9.5%
		CHF - NYHA class 4	19,147	5.5%

SUPPLEMENTAL TABLE 1: POPULATION STATISTICS AND MISSING DATA				
Factors	**Missing**	**Levels**	**No.**	**Summary Statistics**
Angina	731 (0.2%)	No	66,012	19.0%
		Stable	144,701	41.6%
		Unstable	136,897	39.4%
Cardiogenic Shock	371 (0.1%)	Yes	6,224	1.8%
		No	341,746	98.2%
Arrhythmia	451 (0.1%)	Yes	39,363	11.3%
		No	308,527	88.7%
Atrial fibrillation/Flutter	1078 (0.3%)	Yes	25,636	7.4%
		No	321,627	92.6%
Pre-Op Beta Blocker	737 (0.2%)	Yes	244,572	70.4%
		No	103,032	29.6%
Pre-Op Inotrope	1340 (0.4%)	Yes	6,616	1.9%
		No	340,385	98.1%
Pre-Op IABP	565 (0.2%)	Yes	24,083	6.9%
		No	323,693	93.1%
Pre-Op IABP/ Inotrope	44 (0.1%)	Yes	27,868	8.0%
		No	320,429	92.0%
Number of Diseased Vessels	1016 (0.3%)	0	796	0.2%
		1	11,498	3.3%
		2	63,736	18.4%
		3	271,295	78.1%
Left Main Disease > 50%	1005 (0.3%)	Yes	109,544	31.5%
		No	237,792	68.5%
Ejection Fraction	18127 (5.2%)	Median (25th, 75th)		53.0 (42.0, 60.0)
		Mean ± STD		50.9 ± 13.3
		<3 0	20,486	6.2%
		≥30 and < 45	64,821	19.6%
		≥45 and < 60	128,588	38.9%

SUPPLEMENTAL TABLE 1: POPULATION STATISTICS AND MISSING DATA				
Factors	**Missing**	**Levels**	**No.**	**Summary Statistics**
		≥60	116,319	35.2%
Aortic Stenosis	5740 (1.6%)	Yes	7,850	2.3%
		No	334,751	97.7%
Aortic Insufficiency	11829 (3.4%)	None/Trivial	320,658	95.3%
		Mild/Mod/Severe	15,854	4.7%
Aortic Insufficiency	11829 (3.4%)	None	309,074	91.8%
		Trivial	11,584	3.4%
		Mild	12,985	3.9%
		Moderate	2,628	0.8%
		Severe	241	0.1%
Mitral Insufficiency	9543 (2.7%)	None/Trivial	291,418	86.0%
		Mild/Moderate/Severe	47,380	14.0%
Mitral Insufficiency	9543 (2.7%)	None	266,214	78.6%
		Trivial	25,204	7.4%
		Mild	35,658	10.5%
		Moderate	10,541	3.1%
		Severe	1,181	0.3%
Tricuspid Insufficiency	12674 (3.6%)	None/Trivial	312,534	93.1%
		Mild/Mod/Severe	23,133	6.9%
Tricuspid Insufficiency	12674 (3.6%)	None	294,841	87.8%
		Trivial	17,693	5.3%
		Mild	18,765	5.6%
		Moderate	3,924	1.2%
		Severe	444	0.1%
Incidence of Previous CV Interventions	2746 (0.8%)	First Cardiovascular Surgery	323,660	93.7%
		First Re-op Cardiovascular Surgery	19,772	5.7%

SUPPLEMENTAL TABLE 1: POPULATION STATISTICS AND MISSING DATA				
Factors	**Missing**	**Levels**	**No.**	**Summary Statistics**
		At Least Second Re-op Cardiovascular Surgery	2,163	0.6%
Status	0 (0.0%)	Elective	173,608	49.8%
		Urgent	159,845	45.9%
		Emergent	14,095	4.0%
		Emergent Salvage	793	0.2%
Aortic Gradient (mm Hg)	7618 (2.2%)	No stenosis	334,751	98.2%
		Stenosis, gradient < 10	1,154	0.3%
		Stenosis, gradient ≥10 and < 15	1,632	0.5%
		Stenosis, gradient ≥15 and < 20	1,146	0.3%
		Stenosis, gradient ≥20	2,040	0.6%

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
Demographics							
Age	Median	485979	73.0	136229	72.0	349750	73.0
	25th		69.0		68.0		69.0
	75th		78.0		77.0		78.0
	Mean		73.4		73.1		73.5
	STD		5.7		5.7		5.7
	Missing (%)		0.0		0.0		0.0
Age	<70	147734	30.4	44130	32.4	103604	29.6
	≥70 and <75	139480	28.7	39568	29.0	99912	28.6
	≥75 and <80	118712	24.4	31607	23.2	87105	24.9
	≥80 and <85	63757	13.1	16720	12.3	47037	13.4
	≥85	16296	3.4	4204	3.1	12092	3.5
Gender	Missing (%)	34	0.0	34	0.0	0	0.0
	Male	330872	68.1	93742	68.8	237130	67.8
	Female	155073	31.9	42453	31.2	112620	32.2
Race	Missing (%)	3361	0.7	1120	0.8	2241	0.6
	Caucasian	425216	87.5	111502	81.8	313714	89.7
	Black	22835	4.7	8204	6.0	14631	4.2
	Hispanic	14469	3.0	6562	4.8	7907	2.3
	Asian	7717	1.6	3923	2.9	3794	1.1
	Native American	1046	0.2	332	0.2	714	0.2

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	Other	11335	2.3	4586	3.4	6749	1.9
Surgery year	2002	68746	14.1	21211	15.6	47535	13.6
	2003	83063	17.1	21892	16.1	61171	17.5
	2004	81388	16.7	20874	15.3	60514	17.3
	2005	82591	17.0	21337	15.7	61254	17.5
	2006	85713	17.6	24625	18.1	61088	17.5
	2007	84478	17.4	26290	19.3	58188	16.6
Risk Factors							
Weight (kg)	Median	484360	81.1	135716	80.9	348644	81.6
	25th		70.9		70.0		71.0
	75th		92.7		92.0		93.0
	Mean		82.5		82.0		82.7
	STD		17.4		17.4		17.3
	Missing (%)		0.3		0.4		0.3
Weight (kg)	Missing (%)	1619	0.3	513	0.4	1106	0.3
	<70	110250	22.7	32611	23.9	77639	22.2
	≥70 and <80	113578	23.4	32003	23.5	81575	23.3

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	≥80 and <90	112207	23.1	30878	22.7	81329	23.3
	≥90	148325	30.5	40224	29.5	108101	30.9
Height (cm)	Median	484247	171.5	135713	170.2	348534	172.0
	25th		163.0		163.0		163.0
	75th		178.0		178.0		178.0
	Mean		170.3		169.9		170.4
	STD		11.0		10.9		11.0
	Missing (%)		0.4		0.4		0.3
Height (cm)	Missing (%)	1732	0.4	516	0.4	1216	0.3
	<160	78051	16.1	23139	17.0	54912	15.7
	≥160 and <170	123046	25.3	35473	26.0	87573	25.0
	≥170 and <180	180086	37.1	49788	36.5	130298	37.3
	≥180	103064	21.2	27313	20.0	75751	21.7
BMI	Median	482888	27.7	135352	27.6	347536	27.7
	25th		24.8		24.8		24.8
	75th		31.1		31.1		31.1
	Mean		28.4		28.3		28.4
	STD		5.3		5.3		5.3
	Missing (%)		0.6		0.6		0.6
BMI	Missing	3091	0.6	877	0.6	2214	0.6

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	< 20	12594	2.6	3647	2.7	8947	2.6
	≥20 and < 25	115380	23.7	32871	24.1	82509	23.6
	≥25 and < 30	201545	41.5	56344	41.4	145201	41.5
	≥30	153369	31.6	42490	31.2	110879	31.7
Smoking History	Missing (%)	1524	0.3	498	0.4	1026	0.3
	Never	209108	43.0	59581	43.7	149527	42.8
	Past	211247	43.5	58090	42.6	153157	43.8
	Current	64100	13.2	18060	13.3	46040	13.2
Diabetes	Missing (%)	1134	0.2	395	0.3	739	0.2
	No diabetes	309283	63.6	84815	62.3	224468	64.2
	Non-Insulin	128370	26.4	37311	27.4	91059	26.0
	Insulin	47192	9.7	13708	10.1	33484	9.6
Last Creatinine Level Preop	Median	481351	1.1	134726	1.1	346625	1.1
	25th		0.9		0.9		0.9
	75th		1.3		1.3		1.3
	Mean		1.2		1.2		1.2
	STD		0.7		0.7		0.7
	Missing (%)		1.0		1.1		0.9
Last Creatinine Level Preop	Missing (%)	4628	1.0	1503	1.1	3125	0.9
	<1	149669	30.8	42073	30.9	107596	30.8
	≥1 and < 1.5	260297	53.6	72426	53.2	187871	53.7
	≥1.5 and < 2	49136	10.1	13906	10.2	35230	10.1

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	≥2	22249	4.6	6321	4.6	15928	4.6
Renal Failure	Missing (%)	563	0.1	213	0.2	350	0.1
	No	454480	93.5	126952	93.2	327528	93.6
	Yes	30936	6.4	9064	6.7	21872	6.3
Preoperative Dialysis	Missing (%)	842	0.2	308	0.2	534	0.2
	No	478286	98.4	133964	98.3	344322	98.4
	Yes	6851	1.4	1957	1.4	4894	1.4
Hypertension	Missing (%)	301	0.1	121	0.1	180	0.1
	No	85939	17.7	23305	17.1	62634	17.9
	Yes	399739	82.3	112803	82.8	286936	82.0
Chronic Lung Disease	Missing (%)	3915	0.8	1425	1.0	2490	0.7
	No	379281	78.0	106088	77.9	273193	78.1
	Mild	54479	11.2	15170	11.1	39309	11.2
	Moderate	31398	6.5	8902	6.5	22496	6.4
	Severe	16906	3.5	4644	3.4	12262	3.5
Immunosuppressive Treatment	Missing (%)	777	0.2	300	0.2	477	0.1
	No	474697	97.7	133115	97.7	341582	97.7
	Yes	10505	2.2	2814	2.1	7691	2.2
Peripheral Vascular Disease	Missing (%)	540	0.1	207	0.2	333	0.1
	No	394064	81.1	110983	81.5	283081	80.9

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	Yes	91375	18.8	25039	18.4	66336	19.0
Cerebrovascular Disease	Missing (%)	482	0.1	183	0.1	299	0.1
	No	398299	82.0	112549	82.6	285750	81.7
	Yes	87198	17.9	23497	17.2	63701	18.2
Cerebrovascular Accident	Missing (%)	1183	0.2	357	0.3	826	0.2
	None	442031	91.0	123921	91.0	318110	91.0
	2 weeks	1310	0.3	382	0.3	928	0.3
	CVA > 2 weeks	41455	8.5	11569	8.5	29886	8.5
Cerebrovascular Disease Type (CVD Patients Only)	Missing (%)	850	1.0	267	1.1	583	0.9
	Coma	218	0.3	77	0.3	141	0.2
	CVA	31929	36.6	9045	38.5	22884	35.9
	RIND	453	0.5	151	0.6	302	0.5
	TIA	18117	20.8	4785	20.4	13332	20.9
	Non-Invasive >75% stenosis	13979	16.0	3947	16.8	10032	15.7
	Prior Carotid Surgery	21652	24.8	5225	22.2	16427	25.8
Previous Interventions							
Previous CABG	Missing (%)	1416	0.3	429	0.3	987	0.3

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	No	458421	94.3	128978	94.7	329443	94.2
	Yes	26142	5.4	6822	5.0	19320	5.5
Previous Valve Surgery	Missing (%)	1447	0.3	441	0.3	1006	0.3
	No	482766	99.3	135346	99.4	347420	99.3
	Yes	1766	0.4	442	0.3	1324	0.4
Previous PCI	Missing (%)	1575	0.3	470	0.3	1105	0.3
	No	388832	80.0	110205	80.9	278627	79.7
	Yes	95572	19.7	25554	18.8	70018	20.0
PCI within 6 hrs	Missing (%)	3342	0.7	994	0.7	2348	0.7
	No	478343	98.4	134024	98.4	344319	98.4
	Yes	4294	0.9	1211	0.9	3083	0.9
Non Surgical Intervention - Stent Placement (DCF v 2.41 only)	Missing (%)	1210	0.6	366	0.7	844	0.6
	No	172237	86.6	48536	87.3	123701	86.4
	Yes	25358	12.8	6672	12.0	18686	13.0
Risk Factors							
MI	Missing (%)	2818	0.6	874	0.6	1944	0.6
	No Prior MI	271444	55.9	73409	53.9	198035	56.6
	MI / >21 days	85108	17.5	24054	17.7	61054	17.5

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	MI / 8-21 days	17652	3.6	5208	3.8	12444	3.6
	MI / 1-7 days	90895	18.7	27314	20.1	63581	18.2
	MI / 6-24 hrs	11788	2.4	3492	2.6	8296	2.4
	MI / ≤ 6 hrs	6274	1.3	1878	1.4	4396	1.3
NYHA Classification	Missing (%)	18968	3.9	5607	4.1	13361	3.8
	I	59267	12.2	16108	11.8	43159	12.3
	II	122287	25.2	33193	24.4	89094	25.5
	III	182194	37.5	51237	37.6	130957	37.4
	IV	103263	21.2	30084	22.1	73179	20.9
CHF-NYHA	Missing (%)	782	0.2	258	0.2	524	0.1
	No CHF	408399	84.0	113146	83.1	295253	84.4
	CHF - NYHA less than class 4	49060	10.1	14336	10.5	34724	9.9
	CHF - NYHA class 4	27738	5.7	8489	6.2	19249	5.5
Angina	Missing (%)	1116	0.2	363	0.3	753	0.2
	No Angina	90215	18.6	23943	17.6	66272	18.9
	Angina / Stable	199283	41.0	54023	39.7	145260	41.5
	Angina / Unstable	195365	40.2	57900	42.5	137465	39.3

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
Cardiogenic Shock	Missing (%)	629	0.1	242	0.2	387	0.1
	No	476064	98.0	132975	97.6	343089	98.1
	Yes	9286	1.9	3012	2.2	6274	1.8
Arrhythmia	Missing (%)	732	0.2	265	0.2	467	0.1
	No	430875	88.7	121146	88.9	309729	88.6
	Yes	54372	11.2	14818	10.9	39554	11.3
Afib/Flutter	Missing (%)	1581	0.3	483	0.4	1098	0.3
	No	449256	92.4	126363	92.8	322893	92.3
	Yes	35142	7.2	9383	6.9	25759	7.4
Pre-Op Beta Blocker	Missing (%)	1150	0.2	401	0.3	749	0.2
	No	141285	29.1	37866	27.8	103419	29.6
	Yes	343544	70.7	97962	71.9	245582	70.2
Pre-Op Inotrope	Missing (%)	1999	0.4	644	0.5	1355	0.4
	No	474490	97.6	132748	97.4	341742	97.7
	Yes	9490	2.0	2837	2.1	6653	1.9
Pre-Op IABP	Missing (%)	940	0.2	357	0.3	583	0.2
	No	450120	92.6	125148	91.9	324972	92.9
	Yes	34919	7.2	10724	7.9	24195	6.9
Hemodynamics and							

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
Cath							
Number of Diseased Coronary Vessels	Missing (%)	1502	0.3	441	0.3	1061	0.3
	None	1125	0.2	323	0.2	802	0.2
	One	15871	3.3	4295	3.2	11576	3.3
	Two	88190	18.1	24204	17.8	63986	18.3
	Three	379291	78.0	106966	78.5	272325	77.9
Left Main Disease > 50%	Missing (%)	1509	0.3	478	0.4	1031	0.3
	No	331258	68.2	92535	67.9	238723	68.3
	Yes	153212	31.5	43216	31.7	109996	31.4
Ejection fraction	Median	460956	52.0	129477	50.0	331479	53.0
	25th		41.0		40.0		42.0
	75th		60.0		60.0		60.0
	Mean		50.8		50.6		50.9
	STD		13.3		13.5		13.3
	Missing (%)		5.1		5.0		5.2
Ejection Fraction	Missing	25023	5.1	6752	5.0	18271	5.2
	<30	29155	6.0	8569	6.3	20586	5.9
	≥30 and < 45	91156	18.8	26078	19.1	65078	18.6
	≥45 and < 60	178877	36.8	49817	36.6	129060	36.9
	≥60	161768	33.3	45013	33.0	116755	33.4
Aortic Stenosis	Missing (%)	7921	1.6	2147	1.6	5774	1.7

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	No	467151	96.1	131046	96.2	336105	96.1
	Yes	10907	2.2	3036	2.2	7871	2.3
Aortic Insufficiency	Missing (%)	16732	3.4	4795	3.5	11937	3.4
	None	430808	88.6	120536	88.5	310272	88.7
	Trivial	16435	3.4	4806	3.5	11629	3.3
	Mild	18062	3.7	5033	3.7	13029	3.7
	Moderate	3617	0.7	976	0.7	2641	0.8
	Severe	325	0.1	83	0.1	242	0.1
Mitral Insufficiency	Missing (%)	13708	2.8	4061	3.0	9647	2.8
	None	370443	76.2	103163	75.7	267280	76.4
	Trivial	35546	7.3	10271	7.5	25275	7.2
	Mild	49914	10.3	14140	10.4	35774	10.2
	Moderate	14653	3.0	4064	3.0	10589	3.0
	Severe	1715	0.4	530	0.4	1185	0.3
Tricuspid Insufficiency	Missing (%)	17920	3.7	5139	3.8	12781	3.7
	None	411259	84.6	115248	84.6	296011	84.6
	Trivial	24910	5.1	7171	5.3	17739	5.1
	Mild	25790	5.3	6962	5.1	18828	5.4
	Moderate	5471	1.1	1525	1.1	3946	1.1
	Severe	629	0.1	184	0.1	445	0.1
Incidence of Previous CV Interventions	Missing (%)	3827	0.8	1043	0.8	2784	0.8
	First CV	451432	92.9	127004	93.2	324428	92.8

SUPPLEMENTAL TABLE 2: COMPARISON OF STS PATIENTS MATCHED VS. NOT MATCHED TO CMS DATA							
Variable	**Level**	**Overall (N=485979)**		**Not matched (N=136229)**		**Matched (N=349750)**	
	surgery						
	One previous CV surgery	27732	5.7	7422	5.4	20310	5.8
	Two or more previous CV surgeries	2988	0.6	760	0.6	2228	0.6
Aortic Gradient (mm Hg) in Stenoisis Patients	Missing (%)	2560	23.5	675	22.2	1885	23.9
	<10	1612	14.8	456	15.0	1156	14.7
	≥10 and <15	2282	20.9	648	21.3	1634	20.8
	≥15 and <20	1577	14.5	428	14.1	1149	14.6
	≥20	2876	26.4	829	27.3	2047	26.0
Operative							
Status of the Procedure	Missing (%)	528	0.1	200	0.1	328	0.1
	Elective	236364	48.6	62207	45.7	174157	49.8
	Urgent	227617	46.8	67315	49.4	160302	45.8
	Emergent	20274	4.2	6117	4.5	14157	4.0
	Emergent Salvage	1196	0.2	390	0.3	806	0.2

SUPPLEMENTAL TABLE 3: UNIVARIABLE PREDICTORS OF MORTALITY						
		Number of Patients		Kaplan-Meier Estimated Mortality Rate		
		N	Percent	30-days	1-year	3-years
Age (years)	≥65 and <70	51,762	29.7%	1.9%	4.8%	15.5%
	≥70 and <75	49,804	28.5%	2.6%	6.8%	20.3%
	≥75 and <80	43,527	24.9%	3.7%	9.4%	26.6%
	≥80 and <85	23,385	13.4%	5.4%	13.1%	35.2%
	≥85	6,028	3.5%	7.2%	18.0%	45.6%
Gender	Female	56,128	32.2%	4.2%	9.6%	24.3%
	Male	118,378	67.8%	2.7%	7.4%	22.8%
Race/Ethnicity	White	156,538	90.3%	3.2%	8.0%	23.1%
	Black	7,305	4.2%	3.6%	10.4%	29.0%
	Hispanic	3,948	2.3%	3.7%	8.9%	25.1%
	Asian/Native American/Other	5,584	3.2%	2.9%	7.5%	21.5%
Year of Surgery	2002	23,671	13.6%	3.4%	8.3%	23.6%
	2003	30,594	17.5%	3.5%	8.6%	24.0%
	2004	30,141	17.3%	3.3%	8.3%	23.3%
	2005	30,592	17.5%	3.1%	7.7%	NA
	2006	30,539	17.5%	3.0%	8.0%	NA
	2007	28,969	16.6%	2.9%	7.8%	NA
Weight (Kg)	<70	38,659	22.2%	4.6%	11.2%	28.8%
	≥70 and <80	40,863	23.5%	3.2%	8.3%	23.2%
	≥80and <90	40,653	23.4%	2.6%	6.7%	20.9%
	≥90	53,768	30.9%	2.6%	6.7%	21.1%

SUPPLEMENTAL TABLE 3: UNIVARIABLE PREDICTORS OF MORTALITY						
		Number of Patients		Kaplan-Meier Estimated Mortality Rate		
		N	Percent	30-days	1-year	3-years
Height (cm)	<160	27,211	15.6%	4.5%	10.0%	25.1%
	≥160 and <170	43,701	25.1%	3.6%	8.8%	23.8%
	≥170and <180	65,064	37.4%	2.8%	7.5%	22.9%
	≥180	37,905	21.8%	2.5%	6.9%	22.2%
BMI (kg / m2)	<20	4,480	2.6%	7.6%	18.4%	41.8%
	≥20 and <25	41,201	23.8%	3.6%	9.9%	27.3%
	≥25 and <30	72,557	41.8%	2.8%	7.0%	21.0%
	≥30	55,150	31.8%	3.0%	7.3%	21.7%
Smoking Status	Current Smoker	22,983	13.2%	3.6%	9.8%	29.4%
	Past Smoker	76,296	43.9%	3.1%	8.3%	24.4%
	Never Smoked	74,702	42.9%	3.1%	7.4%	20.4%
Diabetes	No diabetes	111,994	64.3%	3.0%	7.3%	20.7%
	Non-insulin diabetes	45,668	26.2%	3.1%	8.3%	25.0%
	Insulin diabetes	16,461	9.5%	4.7%	13.3%	37.0%
Renal Function	No dialysis - Creatinine ≤1.5 mg/dL	153,678	88.8%	2.7%	6.7%	20.5%
	No dialysis - Creatinine > 1.5 mg/dL	16,894	9.8%	6.4%	16.8%	42.2%
	Dialysis	2,409	1.4%	10.4%	31.6%	74.8%
Hypertension	Yes	142,962	82.0%	3.3%	8.4%	24.1%
	No	31,456	18.0%	2.7%	6.7%	20.1%
Chronic Lung Disease	No	136,277	78.6%	2.8%	6.8%	20.2%
	Mild	19,501	11.3%	3.6%	9.9%	28.7%
	Moderate	11,325	6.5%	5.2%	13.7%	37.3%
	Severe	6,199	3.6%	7.7%	20.9%	49.8%
Immunosuppressive Therapy	Yes	3,785	2.2%	6.7%	18.5%	43.6%
	No	170,488	97.8%	3.1%	7.9%	22.9%

SUPPLEMENTAL TABLE 3: UNIVARIABLE PREDICTORS OF MORTALITY						
		Number of Patients		Kaplan-Meier Estimated Mortality Rate		
		N	Percent	30-days	1-year	3-years
Peripheral Vascular Disease	Yes	32,763	18.8%	5.1%	13.4%	35.3%
	No	141,572	81.2%	2.8%	6.9%	20.5%
Cerebrovascular Disease	Yes	31,651	18.2%	4.7%	12.3%	33.1%
	No	142,704	81.8%	2.9%	7.2%	21.1%
CVA	No CVA	158,667	91.1%	3.0%	7.5%	22.1%
	≤ 2 weeks	477	0.3%	4.8%	13.6%	33.8%
	> 2 weeks	14,972	8.6%	5.2%	14.2%	36.0%
RIND	Yes	153	0.1%	3.9%	10.5%	29.0%
	No	173,905	99.9%	3.2%	8.1%	23.3%
TIA	Yes	6,623	3.8%	3.8%	10.3%	29.0%
	No	167,435	96.2%	3.2%	8.0%	23.0%
Non-invasive > 75% Stenosis	Yes	5,010	2.9%	4.8%	11.6%	32.7%
	No	169,048	97.1%	3.1%	8.0%	23.0%
Prior Carotid Surgery	Yes	8,023	4.6%	4.8%	11.7%	32.7%
	No	166,035	95.4%	3.1%	7.9%	22.8%
Prior CABG	Yes	9,336	5.4%	5.6%	11.4%	28.0%
	No	164,662	94.6%	3.1%	7.9%	23.0%
Prior Valve Surgery	Yes	647	0.4%	5.6%	16.1%	42.3%
	No	173,347	99.6%	3.2%	8.1%	23.2%
Previous PCI	Yes	34,908	20.1%	3.5%	8.2%	23.1%
	No	139,059	79.9%	3.1%	8.1%	23.4%
Stent (DCF v2.41 only)	Yes	9,310	13.1%	3.9%	8.3%	23.0%
	No	61,708	86.9%	3.4%	8.4%	23.8%
PCI within 6 hrs	Yes	1,502	0.9%	10.6%	17.4%	30.7%
	No	171,858	99.1%	3.1%	8.0%	23.2%

SUPPLEMENTAL TABLE 3: UNIVARIABLE PREDICTORS OF MORTALITY

		Number of Patients		Kaplan-Meier Estimated Mortality Rate		
		N	Percent	30-days	1-year	3-years
MI	≤ 6 hrs	2,185	1.3%	12.2%	20.3%	33.7%
	> 6 hrs and < 24 hrs	4,117	2.4%	9.0%	16.2%	30.2%
	1 - 7 days	31,969	18.4%	4.9%	11.4%	28.7%
	8 – 21 days	6,324	3.6%	4.9%	14.7%	38.2%
	> 21 days	30,437	17.5%	3.1%	8.3%	25.5%
	No MI	98,517	56.8%	2.1%	5.9%	19.3%
NYHA Classification	Class 1	21,561	12.8%	2.1%	5.9%	19.5%
	Class 2	44,289	26.4%	2.0%	5.6%	18.9%
	Class 3	65,527	39.0%	3.0%	7.9%	23.7%
	Class 4	36,581	21.8%	5.8%	12.8%	29.8%
CHF	No CHF	147,272	84.9%	2.5%	6.3%	19.7%
	CHF - NYHA less than class 4	16,606	9.6%	5.2%	15.3%	39.8%
	CHF - NYHA class 4	9,566	5.5%	9.5%	22.1%	46.8%
Angina	No	32,962	18.9%	3.3%	8.8%	25.8%
	Stable	72,354	41.6%	2.2%	6.3%	20.4%
	Unstable	68,808	39.5%	4.2%	9.6%	25.0%
Cardiogenic Shock	Yes	3,169	1.8%	20.2%	32.4%	49.3%
	No	171,149	98.2%	2.9%	7.6%	22.8%
Arrhythmia	Yes	19,658	11.3%	6.2%	15.5%	37.0%
	No	154,617	88.7%	2.8%	7.2%	21.5%
Atrial Fibrillation/Flutter	Yes	12,755	7.3%	5.8%	15.8%	39.1%
	No	161,201	92.7%	3.0%	7.5%	22.0%
Pre-Op Beta Blocker	Yes	122,690	70.5%	3.1%	8.0%	23.2%
	No	51,457	29.5%	3.4%	8.3%	23.6%
Pre-Op Inotrope	Yes	3,252	1.9%	14.2%	26.6%	47.4%

SUPPLEMENTAL TABLE 3: UNIVARIABLE PREDICTORS OF MORTALITY						
		Number of Patients		Kaplan-Meier Estimated Mortality Rate		
		N	Percent	30-days	1-year	3-years
	No	170,586	98.1%	3.0%	7.7%	22.8%
Pre-Op IABP	Yes	12,106	6.9%	8.4%	15.9%	31.7%
	No	162,119	93.1%	2.8%	7.5%	22.7%
Number of Diseased Vessels	0	381	0.2%	3.4%	8.9%	25.3%
	1	5,829	3.3%	2.4%	5.7%	17.9%
	2	32,111	18.5%	2.7%	6.9%	20.9%
	3	135,683	78.0%	3.4%	8.5%	24.1%
Left Main Disease > 50%	Yes	54,859	31.5%	3.8%	9.5%	26.1%
	No	119,137	68.5%	2.9%	7.4%	22.1%
Ejection Fraction	< 30	10,311	6.2%	7.6%	18.5%	42.3%
	≥30 and <45	32,598	19.7%	4.4%	11.6%	31.8%
	≥45 and <60	64,536	39.0%	2.7%	7.0%	21.2%
	≥60	58,031	35.1%	2.2%	5.3%	17.1%
Aortic Stenosis	Yes	3,978	2.3%	5.6%	14.4%	39.0%
	No	167,661	97.7%	3.1%	8.0%	23.0%
Aortic Insufficiency	None/Trivial	160,698	95.3%	3.1%	7.9%	22.9%
	Mild	6,479	3.8%	4.3%	11.7%	30.9%
	Moderate	1,295	0.8%	6.2%	15.1%	39.6%
	Severe	130	0.1%	6.9%	16.2%	33.0%
Mitral Insufficiency	None/Trivial	146,159	86.1%	2.9%	7.3%	21.9%
	Mild	17,660	10.4%	4.4%	11.4%	30.6%
	Moderate	5,330	3.1%	7.1%	17.5%	39.4%
	Severe	584	0.3%	8.4%	19.9%	44.3%
Tricuspid Insufficiency	None/Trivial	156,606	93.1%	3.1%	7.8%	22.7%
	Mild	9,389	5.6%	4.1%	11.3%	31.0%

SUPPLEMENTAL TABLE 3: UNIVARIABLE PREDICTORS OF MORTALITY						
		Number of Patients		Kaplan-Meier Estimated Mortality Rate		
		N	Percent	30-days	1-year	3-years
	Moderate	1,960	1.2%	7.0%	18.4%	40.4%
	Severe	209	0.1%	8.6%	25.4%	47.8%
Incidence of Previous CV Interventions	First Cardiovascular Surgery	162,177	93.7%	3.0%	7.9%	23.0%
	First Re-op Cardiovascular Surgery	9,877	5.7%	5.4%	11.0%	27.3%
	At Least Second Re-op Cardiovascular Surgery	1,085	0.6%	6.8%	14.8%	32.8%
Status	Elective	86,785	49.7%	2.2%	6.2%	20.7%
	Urgent	80,279	46.0%	3.4%	9.0%	25.1%
	Emergent	7,061	4.0%	10.7%	18.8%	33.4%
	Emergent Salvage	381	0.2%	38.9%	49.9%	61.0%